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TRADITIONAL EARTHEN BUILDING TECHNIQUES IN CENTRAL ASIA

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Abstract

This paper provides an overview of the principal earthen building materials of Central Asia and the cultural aspects of a traditional architecture which incorporates an understanding which dates back centuries. The work was started by focusing on sets of research questions which also helped to structure the study: what are the manufacturing processes of materials in the area? Based on the analysis of materials, what suggestions can be made for a more appropriate conservation of the Central Asian built heritage? There is at present a large lacuna in the literature on Central Asian materials. The traditional processes of production and the traditional methods for repairing require proper documentation. Several craftsmen were interviewed by the author in order to collect data on the traditional process of manufacturing earthen materials. The aim of interviewing local craftsmen through semi-structured interviews was to increase the scant information about the local, traditional techniques of construction and the materials employed.

Keywords

Central Asia, building techniques, mud brick, rammed earth, cob, lime

Introduction

It was calculated that between 60 and 80 percent of the Central Asian dwellings are made of soil (Tulaganov et al. 2005) with the predominant type in the Central Asian steppes being loess (Grajdankina 1989). The common name of loess is aeolian clay, and as this name implies, it is produced by the action of wind erosion on rock. This explains its range of particle sizes, towards the fine end of the normal soils index. Its main constituents are sand, silt and clay, whilst gravel is not present at all. Carbonates and soluble salts content can be high when compared to other types of soils. Both silt and sand are towards the fine range of particle size, and despite the expectation of those accustomed to alluvial soil, who are used to encountering a far larger range of particle sizes, it makes an excellent building material, and is used as such in many parts of Asia. The high content of soluble salts is related to scarce precipitation and to consequential low washing¹.

As for the etymology of technical words mentioned in this paper, it reflects the complex history and the cosmopolitan mix of cultures of Central Asia. To illustrate this, the origin of some words is given here: *kerpich* (brick, Turkic), *qish* (brick, Sino-Tibetan), *rastvor* (mortar, Russian), (*bokh*, West Iranian). This clearly shows that native techniques and methods were developed with introduced skills from other cultures. For a comparative analysis of terms in the main Central Asian languages, see Table 1.

Archaeological evolution of the use of earth as building material

Mud brick

Mud brick is widespread throughout Central Asia where entire medieval cities were built with this technique (for a geographical distribution of the sites mentioned in this paper, see Fig. 1). The peculiarity of such brick is that neither straw nor any other fibre is added to the mix. This is due to the fact that loess soil is often a well graded blend of components and shrinkage cracks rarely appear on mud brick when drying. The most primitive form of mud brick is that of hand-moulded soil loaves, such as those measuring 20-25x60-70 cm that were excavated in the Neolithic site of Dzhejtun (Reutova and Shirinov 2004). In today's Zerafshan valley (stretching from Samarkand to Ainy), soil loaves are still employed for building and the technique might have originated in Uzbekistan where loaves (*gualyak*) are laid both wet and dry (Shroeder et al. 2003; Tulaganov et al. 2005). In Fergana and Zerafshan this primitive form of mud brick, known as *gualya*, was still in use until the second half of the twentieth century (Pisarčík and Yershov 1973).

Nilsen (1966) explains that in ancient times large bricks of varying dimensions were employed in Central Asia: Anau (47x22x10 cm, 500 BC), Namazga-tepa (42-47x22-24x10-12 cm, 2000 BC), and Munchak-Tepa (65x33x10-12 cm) amongst many. From 6th century BC to 6th century AD mud bricks were mainly of square format and were often employed in combination with rectangular bricks. This was documented for instance in Kizil-Kir (Bukhara) where bricks of square format (44x44x10 cm and 42x42x10 cm) alternate rectangular bricks (55x45x10-12 cm). In other sites of the 1st millennium BC, such as Tagisken (Kazakhstan, along the Syr Darya river) square brick dimensions were 50x50x10 cm (Turekulova et al. 2004). Brick sizes were not standardised as it is quite common to find several sizes of brick in the same monument or site. However, between 3rd and 4th century AD brick employed for the erection of platforms or other massive construction were commonly of 40x40x10-11 cm or 41x41x10-12 cm. According to Voronina (1953), mud brick was often employed in combination with monolithic earth to make complex masonry such as those of Penjikent and Aktepa (the latter in the Tashkent region).

¹ Grajdankina (1989) explains that, as a general rule, Central Asian loess soil is characterised by the following components: silica (50-60%), calcium oxides (9-14%, but in areas such as Fergana may be up to 20-25%), gypsum/magnesium oxides (1-3.5%), and other oxides (15-18%, of which ferrous oxides are between 4-7%).

Thickness of horizontal joints vary enormously and this can be manifested in one single building (Voronina 1953), such as the city wall of the second *shakristan* of Krasnaya Rechka (Kyrgyzstan) where mud bricks are laid on a bed of mortar of thickness varying from 1 to 10 cm. The conjecture after the visual inspection is that the mortar may have been used in liquid form, similarly to what explained by Reutova and Shirinov (2004) for the site of Dzharkutan (south Uzbekistan) where joints thickness is of eight centimetres. Shishkin (1963) explains that in the citadel of Dvorez Bukhan-Khudatov (10th-11th century AD), mud brick masonry with joints of 11 cm thickness were found.

Central Asian fortifications are monumental, without galleries in their core, and sometimes built of monolithic earth, but more often with mud brick. Sauran (14th-15th century AD) has one of the better preserved medieval city walls of Kazakhstan. Its mud brick (23x15x8 cm) defensive walls are still standing up to a height of more than six metres (Fig. 2). The site had a short life of only three centuries and amongst the causes of abandonment may be the lack of underground water supply from the Karatau mountains. City wall construction was a gigantic task, for instance the walls of Gyaur-Kala (Merv) were 1.5 km in length with towers every 20 m and height of walls up to 15 m. Similarly in Dallarversin Tepe, along the Surkjan Darya river, the city walls extend to 1 km (Mandelshtam and Levtzner 1958).

In arid areas mud brick was often employed for barrel vaulting, such as those of the Qir Qiz Palace (9th-10th century AD) in the outskirts of Termez and in the defensive walls of Ayaz Kala I (Fig. 3), both located in Uzbekistan. Raspopova (1990) explains that barrel vaults were made with mud brick with small holes on the sides where the mortar was to be applied, so that to improve bonding. According to Raspopova (1990) vaults in Penjikent reached 2.2 m in height. Upon completion of the vault and the floor, another room could be built on top. In so doing, the minimum height of Penjikent houses was 6-8 m, but more affluent dwellings could reach 10 m. More recently, mud-brick domed mausolea (*gumbaz*) are found in the Naryn and Djungal regions in Kyrgyzstan. According to Rapoport and Nieralsik (1984), in Toprak Kala two types of mud bricks were found: rectangular (with dimensions 39.5x40x9-11 cm and made with a mixture of soil and straw, used for the construction of dwellings and fortifications), and trapezoidal (such bricks were for use in the construction of arches and vaults and were made with a truncated pyramid mould. The latter were 18x21 cm wide on the main side and 40x8 cm on the minor side (40 cm in height). Their shape and dimensions facilitated the construction of the vaults without centering. During the manufacturing process of such bricks, a higher percentage of straw was added so that to make them lighter. Furthermore, in order to improve bonding with mud mortar, they were provided with deep finger marks along the length of the face to be bedded.

Turekulova and Turekulov (2004) explains that in Chirik-Rabat, a site located along the Syr Darya river dating 6th to 2nd century BC, layers of reed were inserted in the masonry so that to improve its seismic resistance (this was documented to be in use since the third millennium BC in both Iraq and Iran). In order to have earthquake resistance, walls were built by adding a reed layer before constructing the lifts of monolithic earth and then mud brick would follow alternatively.

In the mountainous areas of upper Zerafshan, mud brick became widespread only in mid nineteenth century, slowly replacing stone. They were also traditionally used as infill in timber framed buildings (Fig. 4). The technique of mud brick making was present in the area before the colonial period, but dimensions of such brick, known as Muslim brick (*bishtī musulmonī*), was larger (40-42x30-31x8-10 cm) than the introduced ones (Pisarčík and Yershov 1973). Since the 1940s brick dimensions became even smaller, being standardized to those of fired brick and took the name of *bishtī urusi* (Russian brick). Some sites have revealed a variety of mud brick sizes belonging to different occupation periods². It should be also mentioned that in the site of Toprak

² In Kampyr Tepa (also known as Kafyr Tepa, south Uzbekistan) early Kushnan bricks (1st century BC) measure 38-40x38-40x12 cm, early Greek or pre-Mongol bricks measure 50x40x14 cm, whilst Greek bricks (beginning of 3rd to end of 2nd century BC) measure 36-37x36-37x14 cm. Pilipko (1985) explains that stamped mud bricks revealing mason marks were found in Merzabek III, site dated 10th century AD.

Kala, massively built with mud brick with standard dimensions (40x40x12 cm), it was common during the moulding process to impress a stamp on the brick, probably to identify the production. Stamped bricks are known to be used in the construction of ziggurats since the third millennium BC in Iraq and Iran.

Turf is used moderately in construction if compared to other techniques. It was documented in Kazakhstan and Kyrgyzstan where it is quarried with special cutting tools and employed dry (Fig. 5).

Pakhsa

In Central Asia both rammed earth and cob are known as *pakhsa* (Figs 8 and 9). Such techniques were employed since pre-Islam time, but they are less ancient than mud brick. In contemporary Central Asia both methods are nowadays mostly employed in rural areas, but mud brick is also present in urban areas. In Afghanistan for instance it was surveyed that 94% of dwellings are made of monolithic earth or mud brick, the rest being made of other materials (Foley 2005).

Pakhsa was often built in juxtaposition with mud brick and in some cases the two were combined in alternate layers. Such stratification was common in the Sogdian site of Kizil Kir (1st century BC) where thick walls of 2.2-2.4 m were built with *pakhsa* blocks measuring 50-55 cm in height between which one course of mud brick (44x44x11-12 cm) was inserted. Similar construction patterns were found in Djumalaktepa (Termez region) and in the Kashkadarya castle of Aultepa where two courses of mud brick were inserted. Ziablin (1961) provides a description of the construction techniques of the second Buddhist temple of Ak Beshim, now entirely decayed after excavation: 'Walls of the second Buddhist temple were made of a combination of *pakhsa* and mud brick. *Pakhsa* was made by ramming local soil in formwork. This technique was found at footing level, and alternate use of one rammed earth lift and three courses of mud brick was the rule. Vertical joints (3-4 cm thick) are alternated to form a stretcher bond between blocks, and this provides evidence that the *pakhsa* walls are made of rammed earth and not cob'. The reason for employing such technique may be double: levelling of the *pakhsa* work after every lift, and reducing shrinkage cracks upon drying.

Generally speaking after the 1st century AD *pakhsa* walls became thinner, showing a more rational approach to the material (Tolstov 1953 and Nilsen 1966). Only defensive walls were more than 2 m thick. The city walls of Qhulbuk (Tajikistan) for instance, dating 9th-11th century AD, are eight metres thick at the base and were originally clad with a skin of fired brick.

Craftsmanship and the role of masons

The site of Penjikent revealed wall drawings that were used as preparatory projects before construction, but written sources are sparse and therefore the closest ones are those available in India such as the *Mānasāra* for instance (Litvinskij and Zejmal 2004). The book, dating between 500 and 700 AD, describes the role of the Master Craftsman not only in the manufacturing of materials, but also in the construction of buildings. Here the Master Craftsman is illustrated as supervisor of the building process and a clear hierarchy is made in terms of main activities and expertise: *sthāpati* (the Master Craftsman who had the role of the chief architect), *sūtragrāhin* (the designer), *vardhakin* (artist and draughtsman, but also craftsman), and *taksaka* (carpenter). Similar terminology can be found in early mediaeval Persian sources (Litvinskij and Zejmal 2004), and it is speculated here that Central Asian craftsmen were hierarchically organised according to the level of experience gained during the apprenticeship. Furthermore, the monumental architecture of Bukhara and Samarkand was traditionally constructed by Master Craftsmen (*gilkor*) who worked with a group of only a few assistants who later would become specialised craftsmen. These were the most experienced individuals who knew the workmanship involved in all aspects of building and the necessary stages of construction. Such Master Craftsmen often worked in the

repair of old building, whilst specialised craftsmen included the stone mason (*devolgor*), the plasterer-carver (*ganchkor*), the mud plasterer (*andovachy*), and the carpenter (*duradgor* or *chubkor*).

In contemporary rural Tajikistan craftsmen are hierarchically organised according to the level of experience gained: main master (*ustó kalón*, the most experienced craftsman who knows all the phases of building a house), second master (*ustó*, experienced in laying bricks and stone), and the young non-experienced worker (*shóghiyrd*). Apprenticeship starts at the age of 16, then after five years of training the unskilled workman is upgraded to master. Similar apprenticeship is found also in rural Afghanistan where specialised masons are contacted only for special work such as the construction of domes (Scherrer 2003). Here masons have different names according to their work: stone mason (*sang tarash*), mud mason (*gelkar*), brick layer (*kehsht kari*), whilst in rural areas masons are simply called *gelkar* (Scherrer 2003). More recently, villages were not organised in a cash economy, as the Kazakh term *assàr* (also found as *hashér* or *hashàr* in Tajik) - which means *returned help* - suggests³. Bartering with labour, vegetables, farm animals, is in fact the most common method of organizing construction until recently.

Several medieval Central Asian cities, such as those of Otrar in Kazakhstan and Gyaurla (Merv), were built on gigantic artificial platforms (locally known as *tobe*, *tepe*, or *tepa*, equivalent to the Middle Eastern term *tell*) made of a grid of mud blocks that was filled with earth deposits. Such monumental platforms, and the extensive system of irrigation channels that accompanied the construction of cities, could be built only with slave-induced work, as suggested by Nilsen (1966). Brikina (1974) explains that between 5th century BC and 9th century AD construction of platforms was made with rammed earth blocks measuring from 70x70 cm to 60x50 cm. In other cases smaller platforms, such as that of the second Buddhist temple in Krasnaya Rechka (Kyrgyzstan), were made before erecting single buildings. Only in some cases the name of the builder is known, such as for the Sultan Anjar minaret in Jar Kurgan, constructed between 1108 and 1110 by the master builder Muhammad Ali.

Mud brick

Soil selection

Soil selection and the making of mud brick differs from area to area, according to the availability of materials and the practical influence of adjacent villages. In mountainous regions soil sources are established by previous generations, whilst in the plains mud brick makers tend to move to those areas where mud is readily available. Testing procedures for the selection of soil are simple. If the soil shows salts efflorescence upon drying, or if does not allow workability by bare feet after wetting, it is discharged and another soil is considered for construction. Soil is tested by moulding one specimen and putting it to dry for four days; if the brick does not show any cracks, it is considered to be of good quality and brick making can start. Another method used by brick moulders for the assessment of a well mixed soil is the following: if a brick can be dropped from a height of one metre without breaking, is considered adequate for use. Generally speaking mud brick making is organised along the strip of land near main irrigation canals, where alluvial deposits produce the best quality of soil because naturally mixed by flowing water. This soil only requires a small amount of straw because the proportion of silt:clay:sand within it produces an extremely compact form of brick. The proximity of the canal is also important for the water needed for mixing. The top layer, containing organic matter, is discharged. Soil is the product of the decomposition of rocks, deposited by the action of water in river banks and streams. The heavier material drops first, followed by silt and clay. Craftsmen therefore choose between two different kinds of fine and coarse soil according to the degree of refinement required. Every craftsman is extremely familiar with those stream banks and locations where the best quality sand is to be found. The quantity of dug soil necessary for building is generally speaking so small that the stream can replenish the amount annually. Furthermore, the streams of mountainous areas

³ The person who returns the help is called *assàrsh*.

carry the best quality of sand because it is rarely mixed with clay or silt in these locations. In the mountainous areas of upper Zerafshan, where good soil is scarce and more valued for cultivation, mud brick walls (*bisht devoi*) are built on unfavourable slopes with the local soil that is quarried during the digging of the foundation or terracing, even if of bad quality (Pisarčík and Yershov 1973).

Mixing

Before moulding the bricks, the craftsmen ensure the evenness of the drying ground with a mattock. Traditional mixing techniques are numerous. The simplest method consists of digging the soil with a mattock in order to break the largest lumps of clay, after which it is wetted with buckets of water and left to soak overnight⁴. The soil is then mixed with water and blended and turned in order to get the right degree of plasticity and homogeneity. The following day the soil is foot stamped and trodden at least twice and watered again. On the third day all the lumps of clay have soaked and after final mixing the soil is ready to be employed. In some building cultures the soil was soaked and left to freeze throughout the winter so that to break the lumps and achieve proper workability (Grajdarkina 1989).

Mud brick moulding and drying

When the mix is ready, bricks are manufactured with a wooden multiple mould (*kolab* in Tajik) made by the local carpenter with boards of 2 cm thickness, with two handles. The dimensions of dry bricks vary from area to area, usually maintaining the proportion 1:2:4. The steps for the moulding of bricks are four (Fig. 6):

- i. Soaking of mould in water. This has the function of saturating the mould so that to allow easy removal of bricks and avoid suction;
- ii. Throwing of clay mixture into the mould. This is done following the traditional method in use in Central Asia, consisting in the throwing of a 'loaf' of mud in the mould, so that to fill it entirely at once. The four corners are then compacted and eventual excess mud is scraped in order to make crisp bricks that would later form straight walls;
- iii. In some areas, such as in the Chuy valley in Kyrgyzstan, the mould has a wooden bottom and is pulled with a string until reaching the moulding area. In so doing the clay mix is vibrated and the pores space consequentially reduced (density is therefore improved);
- iv. Lifting the mould to allow release of bricks on the ground.

Bricks are turned and left to dry for a number of days that vary according to the weather condition, but in the summer it is common to dry them for up to four days before use. On the first two days the main brick face is set on the ground and then turned over onto its stretcher face in order to dry evenly (Fig. 7). When the drying process is over, bricks are checked and corners trimmed and made sharp with a steel scraper. When bricks are not sold or used immediately, they are stored in the field where they are produced. Stacking is carried out so that to leave gaps and to allow proper drying. Stacking techniques and shapes vary, the most common being pyramidal and cubic.

Pakhsha

Cob

For the construction of cob walls only clayey soil can be used. Soil is dug with a mattock and left to soak for at least three days before application. On the second day the soil is mixed by bare feet and watered again. On the third day more water is added until reaching a sticky and firm consistency. After foundations are built with stone and mud mortar, lifts (*katór* in Tajik) are built by adding up diagonal courses of clay cut with a spade (5x20x25 cm) and some trodding down is imparted when stacking. The amount of water necessary for cob construction depends on the

⁴In some areas of Tajikistan the pit for mixing soil is called *loikhona* and can be about one metre deep.

local clay and this is assessed by the master mason. However, the general rule for the optimum water content is that which allows proper staking of mud lifts without collapsing or settling.

The drying period for every lift is of about three days and only then a new lift can be added, so that to avoid eventual collapse caused by the mix plasticity. As a general rule, straw is not added to the mix and consequentially the resulting lifts show vertical shrinkage cracks. These are not considered as relevant to the stability of the structure and are concealed by a thick mud plaster (with 1:1 ratio between clay and chopped wheat straw). Only when waterproofing is needed, such as for the capping of boundary walls, clay is mixed with straw (1:1 ratio). Lifts heights are: 70 cm (first lift at wall base), 40-50 cm (second and following lift). In the Merv region (Turkmenistan) lifts are also of descending height from bottom to top (Cooke 2004): 90-100 cm, 70-80 cm, 60-70 cm, 50-60 cm. Boundary walls are tapered, with lifts thickness of 60 cm at lower level and 40 cm on top, whilst walls for dwellings are of 60 cm thickness. It was calculated that two men can build lifts up to 0.5x0.5x15 m per day. Capping of boundary walls is made with a bed of reeds or canes to which a mix of soil and straw is added.

In Central Asia cob walls are often finished by shaping (*buridan* in Tajik) with a sharp spade so that to trim the excess clay (Fig. 8), but untrimmed walls are also widespread because plastering would form a better key and it would hide all imperfections (this is true especially for boundary walls that are left unplastered). Untrimmed walls are often made regular and vertical by tapping with bare hands. Moulded earth is also found in use, especially in Tajikistan and in the Indian sub continent. The lifts are built on a fired brick or stone foundation and mud is moulded on the wall by hand. Lifts are thicker (50 cm) at the bottom and are thinner (25 cm) at higher level, so that to form tapered sections. Lifts height does not change, being made of regular courses of circa 25 cm.

Rammed earth

Rammed earth is nowadays widespread in Central Asia but Tajikistan, and virtually any type of soil is employed for the construction of walls, as the capacity of grains to stay together (cohesiveness) is imposed by compacting the material with a rammer (Fig. 9). The main advantage in using such technique is that soil does not need to be soaked and mixed before use, because its natural moisture content after quarrying allows proper compactibility. Rammed earth walls are built with the help of a wooden shuttering and their identification is straightforward because, apart from the characteristic joints between lifts, the fabric shows regular patterns of holes that are left after removing the shuttering. After building the stone foundation and fixing the wooden shuttering, soil is poured in and compacted in layers with a special wooden rammer. A bed of chopped wheat straw or reed is applied every 30 cm and also between lifts so that to avoid shrinkage cracks. In some areas such as Ladakh, ring wooden beams are employed between lifts so that to improve earthquake resistance (Sestini 1998). In contemporary Uzbekistan boundary walls are built with crenellated decorations similarly to the city walls of Khiva (Fig. 10). Cooke (2004) explains that in Turkmenistan (Merv region) 'there is very little formal training amongst the builders on techniques, although there is a great deal of knowledge about sourcing of suitable earth and simple methods of testing the suitability of earth used in construction. For example the rammed earth mix is tested after three days of wetting and drying in the sun to improve workability, by two people pulling (one at either end), acknowledging that if the earth breaks in the middle the mixture needs more work'. Due to the compaction that is imparted during construction, rammed earth walls are generally more load bearing than mud brick and are also more resistant against capillarity rise.

Daubed earth

The load bearing structure of daubed earth buildings is based on a primary timber framework on which a secondary frame is nailed and protected with mud layers on both sides, internal and external, buttered in between vertical or horizontal timber laths (Fig. 4). Mud is applied by hand

in order to form a key between the laths. The skeleton is made of timber and posts are roughly squared and placed around the perimeter of the building at 1.5 metres distance apart.

In upper Zerafshan (Tajikistan) timber is employed in juxtaposition with mud brick so that to make earthquake resistant dwellings (*qalamā*). Walls (*sinj devoḷ*) are made with vertical studs (*sutum*) that are joined to horizontal top rails (*sar sinj*) and bottom rails (*tag sinj*) to form rectangular panels. To these, timber bracings (*kaj sutum* or *gusha sutum*) are joined as reinforcement, together with intermediate vertical posts (*sutum*). The infill (10 cm thick) is rarely made of woven wattles and more often of mud bricks of standard dimensions (6x15x25 cm) that are comparatively smaller than the normal mud brick used in masonry (10x15x25 cm). Pisarčik and Yershov (1973) explain that for the construction of public buildings such frames were doubled in thickness and the space between the two skeletons (*dukak*) filled with sand so that to avoid rotting of the timber.

Other uses of earth as building material

Plaster

The most popular soil for the making of mud plaster has a high content of clay which requires a high percentage of straw (*saman*) in order to prevent fracturing after application (Fig. 11). The employment of saw dust was also recorded, but this seems a peculiarity of mountainous areas. Typical volumetric proportions between soil and straw vary between 2:1 and 1:1, according to the clay content. In upper Zerafshan plaster was made with decreasing straw (*khas*) length from inside to outside, from scratch coat (*panjakash*, or made with fingers) to skim coat (*gul andovā*, or flower plaster). The mix for the scratch coat is selected in order to exclude aggregate larger than one centimetre, and in order to do so the soil is often sieved (2-3 mm sieve). It is prepared in advance and left to soak overnight in order to avoid cracks caused by unsoaked lumps. Then soil is added with chopped straw of 1-3 cm in length and thoroughly mixed. Another mixing technique for plaster employs a wooden container on which soil and chopped straw are mixed dry, then this mix is put on one side of the container and on the other half water is added. The mix is then soaked slowly so that water turns into a slurry and then more mix is added until the consistency of plaster is achieved. This method has the advantage of controlling the optimum moisture content of plaster. The mix is then applied directly to the earthen wall to fill in the cavities and, after being levelled, enable the next layer to adhere. Rough coats were applied in strips in order to make the levelling process lighter, the number of strips being proportional to the strength of the operator. The skim coat was sometimes smoothened⁵.

Shishkin (1963) explains that in the site called Dvorez Bukhan-Khudatov, dating 8th-9th century AD, plume-shaped reed flower heads were employed with straw for the making of mud plaster. Organic admixtures started to be employed only recently (especially by German communities living in Central Asia) in concentration close to 10% for plaster. This makes identification difficult because there are no laboratory tests available today for such low concentrations. The employment of admixtures in plaster is considered to be especially necessary when the soil is not coherent enough. Additives such as horse or donkey dung were traditionally added to the mix to give it a remarkable cohesive strength; the resulting increased water resistance of the plaster is an intentional side effect. Soil and dung are left to soak overnight and the following day the soil is mixed by bare feet, watered again, and mixed with chopped wheat straw in percentages which can vary from village to village. The amount of straw and water is directly proportional to the content of clay in the soil, but usually in concentrations close to 1:1.

⁵ The advantage of using organic fibres in mud plastering is yet to be revealed by current research. However, it is certain that the use of straw produces thicker renders, and that its use in soils with high clay content reduces the risks for cracks. Organic fibres may improve the resistance to water, introducing a stronger connection between clay wafers and hindering dispersion.

When mud plaster was not built straight and showed irregular surfaces, women learnt how to camouflage this by smoothing with a cloth that was wetted in a clay slurry and applied on the wet plaster, the final effect being a coat which hid the irregularities (Pisarčík and Yershov 1973).

Mud was heavily employed in the form of mortar for the setting of fired bricks structures of 9th-16th century AD (Grajdarkina 1989). Examples of this kind are some of the structures of Otrar Tobe (15th-16th century AD mosque, Kazakhstan) and Burana (11th century AD mausolea, Kyrgyzstan) where soil is employed as dug, but also mixed with gypsum⁶.

Flat soil roofs

Before the Soviet domination mud roofs were traditionally widespread throughout Central Asia, but nowadays are present in remote and mountainous regions only (Figs 12, 13, 14). In the rugged areas of upper Zerafshan, Tajikistan, flat soil roofs are still constructed today as in pre-Soviet era. In this sense the area can be considered as a case study to understand how roofs were built in Central Asia in pre-Soviet era. In Zerafshan (villages of Vorú and Gazà) construction of flat roofs (*bom*) begins with the setting of pine or poplar joists (*bolór*) to which a secondary wooden frame (*vassà*) is joined. Then a mat of straw, reed, shredded bark (*puslóg*), or other dry vegetation is applied so that to form a separation layer between the timber and the clay that is then poured on top. Such mat of dry vegetation of about 15 cm thickness provides good climatic insulation and avoids timber to rot. The first layer of clay (5 cm) is made of soil that is collected near the site (*guragbil*) and to this a layer of 25 cm of grey soil (*ghil*) is added⁷. This is done by ramming the grey soil (*ghil*) that is the product of decomposition of slate (*tobà*), with no organic additives added⁸. Such layer is applied only after the first rain because in so doing the soil is naturally moist and compaction on the roof structure is more effective. According to Pisarčík and Yershov (1973) in other villages of upper Zerafshan the nature of soil used for the top layer varies according to the geology of the area and its colour can be yellowish (*zardhok*, in village Matcha), darkish (*ghili sijoh*, in Falgar), and blueish (*ghili kabut*, in Zavron).

Such mud roofs are effective against water erosion and they rely on their thickness for avoiding water penetration. Perimetral low parapet walls (20 cm), called *pardabóm*, are covered with a mix of straw and clay (1:2 by volume) that is dug near the construction. Local craftsmen explain that little maintenance is needed and in some cases the first leaks appear only decades after construction. However, maintenance is carried out every five years by adding a layer of grey clay of 2-3 cm. This is necessary to replace the material that is eroded by rain and the soil that is scraped when cleaning the roofs from excess snow. Provision of proper slope and water sprouts is essential. The slope is provided when applying the mat of reed or bark and the connection of timber sprouts to the low parapet wall is one of the most important architectural details. Their setting into the wall is ensured with heavy stones, and they are of a certain length to avoid splashing of water onto the wall.

⁶ In contemporary Kazakhstan, in the loess steppe area of Shaul Der between Turkestan and Shymkent, plaster is made of a mixture of soil and lime. Outer coats have the following composition: 4 parts sand (Arys river banks), 1 part clay, 1 part lime putty (limewash is then employed as a protective skin). Inner scratch coats have the following composition: scratch coat: 1 part of clay and 1 of straw. Inner skim coats are made with same ingredients as for outer layer (and limewash as a protective skin).

⁷ The experimental analysis of the grey soil (greenish grey, 5/1 gley 1) showed that the carbonates content is within the range of 32-50%, whilst the soluble salts content is minimal (around 1%). The analysis of the brown soil (pale brown, 6/3 10YR) gave the following values: carbonates 28%, soluble salts 1%.

⁸ Pisarčík and Yershov (1973) explain that only in village Shing one wooden rammer (*bomkun*) surveyed. The block measured 25 cm in height and 50 cm in diameter, but does not seem to be a widespread tool in the area

Flat roofs are widespread in neighbouring countries to Central Asia, especially in the area stretching from Daghestan to Ladakh where a red alluvial soil is mixed with straw and applied on a layer of straw or willow twigs. These are necessary to separate the soil layer from the secondary wooden structure so that to avoid rotting (Chayet et al. 1990). Wulff (1966) explains that in the Iranian Plateau flat roofs are made with a mixture of lime, soil, salt (necessary to keep insects away), and straw. Such mix is placed in thin layers that are compacted with a stone upon drying. Differently from the flat roofs of the upper Zerafshan of Tajikistan, such roof needs compacting after every rain and snow is removed instantly to avoid melting and consequential penetration of water.

Floors

Earthen floors are traditionally built in layers (Fig. 15). Floor construction starts with the digging of soil and filling with stones so that to avoid rising damp. The first layer (up to 50 cm) is made over the stone or over the rough surface that is to be paved. The prime material for this layer is unsieved loam which is rammed with a special wooden rammer or with a stone. Only when the first coat has achieved optimum bearing capacity, is the finishing coat of mud mortar (5-7 cm) applied. Its composition is similar to that of mud renders, but with higher straw content so that to avoid shrinkage cracks caused by the thickness of the coat. Before the drying process is complete, the finishing coat is wetted and smoothed with a stone - more recently this is done with a trowel. Cracks are avoided by dampening the finishing coat with water. No waterproofing material is added in the final stage and this is the reason why the last layer is renewed regularly.

Gypsum

In the context of Central Asian monuments gypsum-based mortar is locally known as *ganch*. As a broad classification, three types of *ganch* mortar can be distinguished⁹: *ganch bach* (a mix of gypsum and soil with varying mix ratios that was employed in the lower courses and in the core of walls), *tes ganch* (a mix of gypsum and soil with gypsum content up to 70% that was employed in structural parts such as arches, upper parts of buildings, and pillars), *gul ganch* (a mix of gypsum and soil with gypsum content varying from 70% to 100% that was used for rendering).

Ganch was heavily employed in Central Asia for interior architectural decorations. This is mainly due to its lightness and to its setting speed. Moulds were employed when patterns needed repeating. It should be also mentioned that gypsum plaster was rarely applied in vernacular construction and was rather used for religious buildings and grander houses, often finished with limewashing.

Lime

In the past Central Asia lime was often regarded as an unsuitable binder and this was often substituted by gypsum. The historic picture however differs from modern practices. It has been noted that a range of pozzolans have been used in both mortar and render applications, and it is not yet known or established if lime was available in natural hydraulic forms.

The setting and hardening agent is often non-hydraulic lime which may contain pozzolanic admixtures. For instance, bath house floors needing a 'waterproofing' agent were often built with lime mortars with ashes and/or crushed fired brick as aggregate. If the aggregate of the mortar is not pure and contains fired clay impurities (alumina and silica), the resulting lime might be characterised by feeble to high hydraulic properties and by setting and carbonating in damp condition or in water. This conjecture is confirmed by the literature: 'in most areas of the Islamic world gypsum was the common cementing material of plasters and mortars. Gypsum...could be fired at a much lower temperature than lime, an important factor in areas where wood was scarce or other fuels expensive. Lime plaster was reserved to waterproofing roofs, canals, and drains'

⁹ Lubov Charlina and Elena Khorosh, pers. comm. The common word for gypsum is *gach* (Iran) or *ganch* (Central Asia)

(Lewcock 1978). The literature on the topic refers to this type of mortar as *kȳr* (this being the term used in Central Asia). For instance, lime mortar for the paving of basins of the Otrar bath house (14th-15th century AD, Kazakhstan) showed presence of ashes and crushed fired brick and it is possible that these were added to the mix in order to provide it in the long term with hydraulic properties. The conjecture here is that reed ashes were employed as aggregate in the mortar mix for their pozzolanic properties. Another traditional additive to lime is animal hair that is combined to the mortar only at knocking up stage and just before use, because it may be damaged by uncarbonated lime (Gurmeet and Paromita 2006).

Hillside kilns

In hilly or mountainous settings the most common type was the hillside kiln (*keumdon* in Tajik) with a circular base, measuring roughly six metres in height and with diameter of 4 metres (Fig. 16). The hillside kiln has three advantages when compared to the flare kiln: its top is more easily accessible for loading and its bottom for firing, it has a higher thermal capacity because it can take advantage of the natural slope of the hill itself, and can therefore function more effectively under expansion during the burning process.

The burning process starts with the gathering of the best limestone (*sanghi obak* in Tajik), which is quarried by hand. Before the charging process, the retaining inside wall of the kiln has to be repaired regularly. A rough dome is then built at the bottom (Fig. 17). This is necessary for holding the charge of the stones and occasionally cantilevered monoliths protruding from the wall surface were used for this purpose. Larger stones (the largest being one metre in length) is set at the bottom over the rough dome, followed by stones of a decreasing size until gravel of four centimetres in diameter is placed on top. This arrangement is necessary because larger stones, which require a higher burning temperature, have to be closer to the source of heat. On the contrary, smaller sized and softer stones can be more distant from the fire. The loading process can take up to one week (six workmen).

Kindling, a mix of straw and tar, is inserted through the draw hole which is made of three rough limestones forming a lintel over two pillars. The kindling is used because the flames are more important than the level of heat because stones have to burn, not simply to heat up. The lime burner is a skilled professional who could judge the progress of the burning process simply by checking the smoke rising from the inlets. Burning lime is time and energy consuming as it last for eight days and eight nights and the kiln needs to be fed constantly. Lime burners wait for between three and five days until the kiln has cooled down, depending on the size of the kiln. Quicklime drawing is carried out by using steel hooks, especially when stones are to be melted together because of the high temperature (Fig. 18).

Fired brick and stone

Fired brick appeared for the first time in Central Asia between 6th-7th century AD in the region of south Uzbekistan in the Northern Tokhrastian settlements, and in Kanka in the Tashkent region (Reutova and Shirinov 2004). Gudkova (1964) found mason marks in fired bricks: 38 different symbols were surveyed in Tok Kala (Karakalpakstan, 9th-11th century AD) and marks were found also in sites located in Khoresm between Nukus and Khiva. According to Nilsen (1966) fired brick starts appearing in Central Asia only during the 8th century AD and its massive employment is recorded between 9th-11th century AD. This is especially true for urban settings, however in rural areas both dwellings and religious architecture continues to be built with earth. According to Raspopova (1990), foundations in 7th-8th century Penjikent were made of river rounded boulders and if the wall was to be higher than normal, a *pakhsa* lift was built on the stone foundation and then mud brick coursing was added because lighter.

Stone as building material is widespread only in mountainous areas. In other areas it was employed in the construction of plinths in mud buildings, usually with separation matting made with reeds or canes, according to availability. This helped against decay due to combined action

of rising damp and soluble salts. Before the advent of mud brick stone was the main building employed in upper Zerafshan and it can be classified as follows (Pisarčik and Yershov 1973): *sangi shakeb* (mountain stone), *sangi dandona* (tooth stone), and *sangi rakehdor* (cut stone). This is typical of upper areas, whilst in the valley only smooth round stones are found (*sangi lunda*) and employed especially for fencing. Another type of rounded stone (*sangi safed*) is more suitable for construction because its rough surface allows proper bonding with the mud mortar.

Conclusion

The paper is a first attempt in showing the variety of contemporary earth construction techniques of Central Asia. Some topics needing further research have been identified:

1. survey of geographical distribution of the earthen heritage and of building materials;
2. survey of building types (type of the mountains, type of the plains);
3. experimental analysis of building materials. This could be a systematic research programme which would involve scientists and professionals in conservation. A wide number of samples to be collected, and the analysis to be preferably carried out using rigorous statistical methodology in order to form a comprehensive study of loam as building material in Central Asia.

The latter is especially important for characterizing the use of loess clay in construction and in conservation. The author's direct experience in the conservation of several sites in Central Asia showed that loess clay differs greatly from region to region and that its employment can be a complicated task. It is therefore proposed here that the experimental study of clays could form the basis for good conservation practice.

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Table 1. Comparative analysis of main conservation terms in English, Russian, Kazakh, Kyrgyz, Tajik, and Uzbek

English	Russian	Kazakh	Kyrgyz	Tajik	Uzbek
Clay	Glina	Saz	Topò	Hokh / Gyl	Hokh
Crushed fired brick	Croshka	Talkan	Talkan	Sang porah	Risht kul
Fired brick	Kirpich	Qish (Kirpish)	Qish	Khysht	Khysht
Gravel	Gravi	Shirshk tas	Shaghil	Reg	Reg
Gypsum	Gyps	Gyps	Gyps	Gyps	Gyps
Lime	Izvest	Akh	Akhitash	Ohakh	Ohakh
Loess soil	Loess	Loess	Topò	Jangàl	Jangàl
Monolithic earth wall	Pakhsa	Pakhsa	Bakchà	Loi devor	Pakhsa
Mortar	Rastvor	Lai	Lai	Loi	Loi
Mortar (gypsum based)	Ganch	Ganch	Ganch	Gaaj	Ganch
Mortar (lime and ashes)	Kyr	Kyr	Kyr	Kyr	Kyr
Mud brick	Syrtsovyi kirpich / Seriez	Kessèk	Kessèk	Khishti Khom	Gisht
Mud slurry	NA	NA	NA	Loi ka	Loi sherdon
Plaster	Stukatur	Slak	Shibàk	Stukatur	Stukatur
Plaster (clay and straw)	Saaman	NA	Saman	Andovà	Andovà
Sand	Pesok	Kum	Kum	Khum	Khum
Silt	Il	Batpàk	NA	Gard / Chang	Chang
Soil	Pochva	Topràk	Topuràk	Hokh	Turpók
Straw	Saloma	Saban	Saman	Kahy Gandun	Somon



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Fig. 16. Traditional lime kiln showing heavy buttressing against thermal expansion, Kurgan Tobe region, Tajikistan, 2006



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